No. 873,703. PATENTED DEC. 17, 1907.

E. H. ANDERSON.

ELECTRICALLY PROPELLED CAR OR LOCOMOTIVE.

APPLICATION FILED APR. 5, 1906.

2 SHEETS—SHEET 1.

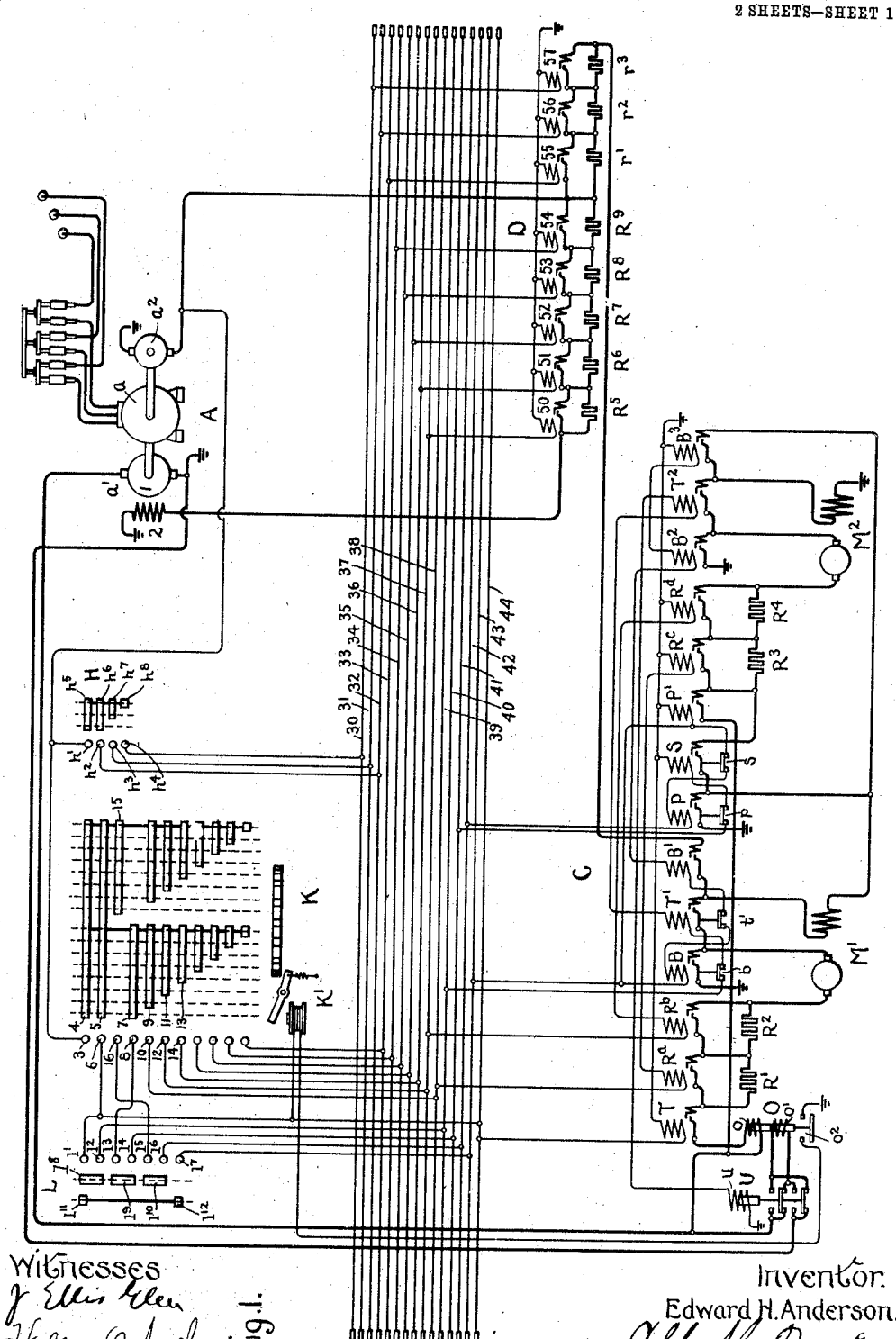

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Fig. 1.

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2 SHEETS—SHEET 2.

Fig. 2.

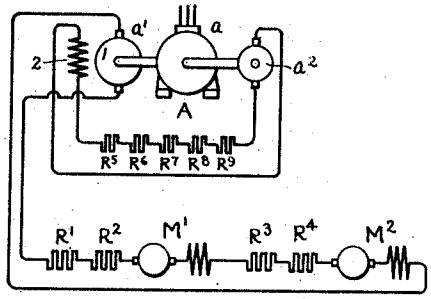
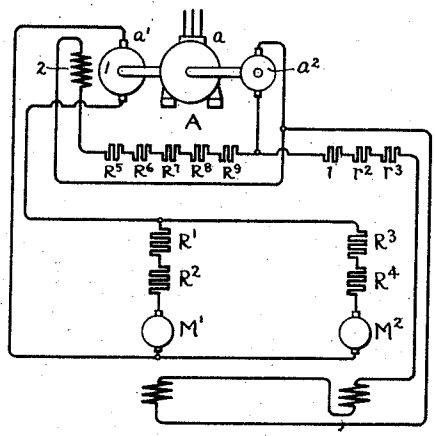


Fig. 3.



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UNITED STATES PATENT OFFICE.

EDWARD H. ANDERSON, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

ELECTRICALLY-PROPELLED CAR OR LOCOMOTIVE.

No. 873,703. Specification of Letters Patent. Patented Dec. 17, 1907.

Application filed April 5, 1906. Serial No. 310,059.

To all whom it may concern:

Be it known that I, EDWARD H. ANDERSON, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Electrically-Propelled Cars or Locomotives, of which the following is a specification.

The present invention relates to electric railways and particularly those wherein the current which is supplied to the cars or locomotives has a high voltage. The most satisfactory type of motor for use in railway work is a simple series motor which, whether operating on alternating or direct currents, may be used to advantage only where the terminal voltage is comparatively low. Therefore, where the line voltage is high, it is necessary to provide some means on the car or locomotive for reducing the potential to a suitable value. Such means may advantageously consist of an induction motor operated directly by the high-potential current and a generator driven by the induction motor and adapted to supply current to motors of the vehicle; and, although my invention, in some of its aspects, may be used under other conditions, it is especially applicable to systems of this character.

In one of its aspects my invention relates to a control system whereby the usual series motors are made to operate effectively not only as motors but also as braking generators driven by the load and supplying energy to the line. This regenerative feature is of importance in that it saves the wear upon the drivers which results from the application of brake shoes and obviates the dangers resulting from tires which are broken or overheated during braking by means of friction shoes: it is of even more importance in railway systems having numerous or long inclines, since a considerable saving in power may be effected while at the same time the speed of car or train may be controlled much more smoothly and effectively in passing down inclines than through ordinary brakes.

It is of importance that the motor-generator set be as small and light as possible, not only for the purpose of decreasing the cost, but on account of the limitations in the space available and because the dead weight factor cannot be ignored as it might be in apparatus for station work. The size of the motor-generator set of course depends largely upon the use to which it is to be put, that is, whether or not it is to be subjected to heavy overloads at times. If heavy overloads can be avoided the apparatus may of course be given minimum dimensions; but if provision must be made for such overloads, larger and heavier apparatus is required.

Therefore one of the objects of the present invention is to provide protective means whereby the load upon the motor-generator set is prevented from being carelessly raised beyond defined limits, in order that the size of the apparatus may safely be reduced to a minimum.

The present invention in its various aspects will be more fully understood and its objects and advantages will more clearly appear from the following description taken in connection with the accompanying drawings which illustrate a preferred form of the present invention.

In said drawings: Figure 1 indicates diagrammatically a complete equipment for one locomotive or other vehicle; Fig. 2 is a diagram showing the main circuits under normal operation of the motor to propel the locomotive; and Fig. 3 shows the principle circuits when the motors are being used as braking generators.

In the drawings a two-motor equipment for a car or locomotive is shown, although it is of course evident that the number of motors may be and usually would be increased.

M^1 and M^2 are the main motors, these being of the usual series type.

A represents a motor-generator set carried upon the car or locomotive and consisting of the induction motor a and the generator a^1. The generator a^1 consists of an armature 1 and a field winding 2, the field being separately excited, as by means of a second generator a^2 also driven from the induction motor.

R^1 to R^4 are resistance sections adapted to be connected in the circuits of the motors M^1 and M^2, and R^5 to R^9 are resistance sections which may be included in series with the field winding 2 of the generator a^1. r^1 to r^3 are resistance sections adapted to be included in circuit with the field of the motors when these motors are operating as braking generators.

C is a controller of the separately-actuated contact type arranged to connect the motors M^1 and M^2 to the armature 1, first in series

with each other and with the resistance R^1 to R^4, then eliminate the resistance, then connect the motors in parallel with resistance again in circuit and thereafter again eliminate the resistance. Certain of the contacts of the controller C are adapted to connect the field windings of the two motors in a circuit independent of the armature and deriving current from the exciter a^2.

D is a controller comprising a plurality of contacts, each of which is adapted to eliminate one of the resistance sections R^5 to R^9 and r^1 to r^3.

K is a master controller adapted to govern the operation of the contacts of the main controller C and that portion of the controller D which governs resistance sections R^5 to R^9.

L is a commutating switch having power and braking positions; this switch coöperating with the master controller to produce either power or braking connections for the motors.

H is an auxiliary master controlling switch for governing that portion of the controller D which affects resistances r^1 to r^3. The master switch devices are connected to the controller-actuating means through a set of train wires 30–44 which may be connected to a similar set of wires upon one or more other vehicles so that one set of master switches may serve to control the equipments of a plurality of vehicles.

O is a relay having one coil o in series with the armature of the generator a^1 and a second coil o^1 in shunt thereto. The two coils on the relay are adapted to assist each other and they are so designed that, if either the voltage across the terminals of the generator armature or the current supplied by the armature rises beyond a predetermined value, the core of the relay will be lifted and will also be lifted when the product of the voltage and current exceeds a predetermined value. This relay may be used to protect the generator so that the output of the generator shall not exceed a predetermined value, namely, that value which will cause the combined action of the potential and current to operate the relay, and furthermore the current which may be supplied at very low voltages may be limited in the same manner. It is of course evident that the relay may be utilized in various ways, as for example, by opening and closing a circuit through a controller locking device K^1, as illustrated.

Assuming that the induction motor is in operation and it is desired to start the car or train; the switch L is turned into the position wherein the right-hand set of movable contacts engages with the fixed contacts and thereupon, upon turning the controller K to its first running position, a circuit may be traced from one terminal of the exciter, through contacts 3, 4, 5 and 6 of the controller K, to train wire 44, and thence through the actuating coil of switch T, to ground. And, since the opposite terminal of the exciter is connected to ground, the actuating coil for switch T is energized and this switch is closed. A branch circuit passes from contact 6, through contacts l^1, l^8 and l^2 of the switch L to train wire 40, and thence through interlock b, associated with switch B, through the actuating coils of switches T^1 and T^2, through the actuating coil u of switch U, to ground. Switches T^1 and T^2 are thus closed and switch U, which is adapted to reverse the connections of the coil o^1 of the relay O, is raised. Another circuit may be traced from controller contact 7 which is connected to contact 5, through contact 8, through contacts l^3, l^9, l^4, of the switch L, train wire 41, and thence through interlock p associated with parallel switch P, through the actuating coil of series switch S, to ground; thus causing the series switch to close. A motor circuit may now be traced from the upper terminal of the generator armature, through relay coil o, through switch T, through resistance R^1, R^2, through the armature of motor M^1, through switch T^1, through the field winding of motor M^1, through switch S, through resistances R^3 and R^4, through the armature of motor M^2, through switch T^2, through the field winding of motor M^2, to ground. The motors are therefore connected across the terminals of the generator armature in series with each other and in series with the resistances as indicated in Fig. 2. Upon turning the controller K to the second position, a circuit passes from contacts 9 and 10 of the controller to train wire 39, and thence through the actuating coils of switches R^a and R^c, to ground; the closing of these latter switches cuts out resistance sections R^1 and R^3. In the third position of the controller a circuit leaves controller contacts 11 and 12 and passes to train wire 38 and thence through the actuating coils of switches R^b and R^d, to ground; these two latter switches close and cut out resistance sections R^2 and R^4. In the fourth running position of the controller a circuit passes from contacts 13 and 14 of the controller, to train wire 37 and thence through the actuating coil of switch 50, to ground. The switch 50 closes and cuts out resistance section R^5, thus strengthening the generator field and increasing the electromotive force at its terminals. Similarly, in the fifth, sixth, seventh and eighth positions of the controller the switches 51, 52, 53 and 54 are closed, short-circuiting, respectively, resistance sections R^6 to R^9, and in each instance increasing the field strength of the generator. In the ninth position of the master controller, contact segment 7 leaves contact 8 and therefore the circuit for the

series switch S is interrupted. Similarly, all the resistance controlling contact segments leave the coöperating fixed contacts and all the resistance switches open. Contact segment 15 now, however, engages with contact 16 and since this segment is connected with the remaining movable segments of the controller, current flows from contact 16, through contacts l^5, l^{10} and l^6 of the switch L, train wire 42, through the actuating coil of the switch P, through interlock s associated with the series switch, through the actuating coil of switch P^1, to ground. Switches T, T^1 and T^2 remain closed in all the running positions of the controller, so that after the switches P and P^1 have been operated the two motors are connected in parallel and each has in circuit therewith the corresponding resistance sections. The excitation of the generator field is again at its lowest, so that upon turning the master controller K through the succeeding running positions the resistance sections R^1 to R^4 in the motor circuit are eliminated and then the resistances R^5 to R^9 in the generator field circuit are short-circuited step-by-step as before.

It will be seen that if at any time the current supplied to the motors exceeds a predetermined value the relay O will be operated, closing its contacts o^2 and completing a circuit through the locking device K^1 of the master controller. Upon being energized the locking device prevents the controller from being moved further until the current has been reduced. Similarly, if the total output of the generator exceeds a predetermined maximum the relay will operate to protect the motor generator even though the current may not exceed a safe value.

When it is desired to brake, the switch L is moved into the position wherein the left-hand movable contacts engage the fixed contacts and then, upon turning the controller K to the first position, the only control circuits which will be established will be the circuits through the contacts 3, 4, 5, and 6 of the master controller, through the actuating coil of switch T, to ground, and a branch circuit passing from contact 6 through contacts l^4, l^{11}, l^{12}, l^7, and thence through the actuating coil of switch B, through the interlock t^1, associated with switch T^1, through the actuating coil of switches B^1, B^2 and B^3, to ground; this latter circuit also branching and passing through the actuating coil of switch P^1, to ground. Switches T, B^1, B^2, B^3 and P^1 are closed and the circuits are as indicated in Fig. 3, namely, the motor armatures are connected in parallel to the generator and have included in circuit therewith the resistance sections R^1, R^2 and R^3, R^4. The field windings of the motors are, however, connected in series with each other and with the resistance sections r^1 to r^3, to the exciter; so that the motors operate as separately-excited generators supplying current to the generator a^1 which now acts as a motor and drives the motor a above synchronism so as to return energy to the line. It is evident that the field windings may be otherwise connected and may be excited in any suitable manner; but, by connecting them in series, the total exciting current is reduced, and by properly proportioning the parts the same exciter may be made to serve to supply current both to the field winding of the generator a^1 and to the field windings of the motors. The master controller may now be operated so as to cut out the resistances R^1 to R^4 and then to strengthen the generator field by cutting out resistances R^5 to R^9 in the same manner as when controlling the speed of the motors in propelling the car or train.

Various arrangements of switches for permitting the motors to be operated both as motors and as generators may of course be employed, but that illustrated is advantageous on railways in which there are long or numerous inclines. In such cases, in starting the descent of an incline, the switch L is placed in the braking position. When the controller K is then brought to its first position the motor circuits are arranged as shown in Fig. 3. The resistances R^1 and R^2 are connected in series with the armature of motor M^1, and resistances R^3 and R^4 in series with the armature of motor M^2, and these resistances serve to prevent an excessive rush of current should there be a large difference of potential between the armatures of motors M^1 and M^2 and the armature a^1 of the generator. If it is desired to decrease the braking action, or in other words, to accelerate the car or train, the controller K is turned in the "on" direction. In the 2nd position of the controller the resistances R^1 and R^3 are cut out, and similarly in the 3rd position the resistances R^2 and R^4 are cut out, thereby connecting the armatures of the motors M^1 and M^2 directly to the generator armature a^1. In the 4th, 5th, 6th, 7th and 8th positions the controller cuts out the resistances R^5 to R^9 thereby increasing the excitation and the E. M. F. of the generator armature a^1. This decreases the current and braking effort of the armatures of the motors M^1 and M^2. Armatures M^1 and M^2 will then run at higher speeds in order to generate the E. M. F. required by the increased E. M. F. of the generator armature produced by cutting out the resistances R^5 to R^9 in the excitation circuit. In this way the speed of the car or train is allowed to increase. To thereafter decrease the speed of the train the controller is moved in the "off" direction thereby reinserting the resistances R^5 to R^9 and finally reinserting the resistances R^1 to R^4 in order to prevent excessive current in the ar-

matures of the motors M^1 and M^2 and in the armature a^1 of the generator. During these operations, however, the operator is prevented from increasing the braking action too rapidly, by means of the relay O and the locking device K^1. When the controllers are being operated to connect the motors as braking generators the actuating circuit for the switch U is interrupted and the connections between coil o^1 of the relay and the armature of the generator a^1 are reversed, so that although the direction of the current in the coil o of the relay is the reverse of that during normal operation of the motor, the relative energization of the two relay coils remains the same. Therefore if, after the train has been brought to speed, the master controller is moved back suddenly so that there is danger of overloading the motor-generator set, the relay operates to close the circuit through the locking device and the controller is locked until the danger of overload is past. The danger of damaging the system by bringing the controller from the "off" position to the first position while the train is running at a considerable speed is obviated by the use of the resistances R^1 to R^4 which serve to materially cut down the currents. It is therefore possible to produce a very quick and effective braking action in case of emergency without turning the controller through a number of positions.

The braking action of the system may be controlled not only by adjusting the field of the generator, which is now operating as a motor, but by varying the excitation of the fields of the motors themselves. Thus the train may be slowed down either by decreasing the generator field or increasing the field of the motors. The system is illustrated as containing normally a resistance r^1 to r^3 in the circuit of the motor fields when the motors are operating as braking generators and these resistance sections are adapted to be short-circuited by switches 55, 56 and 57, which are in turn controlled by the master switch H. In the first operating position of the switch H, current flows from the exciter, through contacts h^1, h^5, h^6, h^2, to train wire 32, thence through the actuating coil of switch 55, to ground and back to the exciter. In the second running position of the switch H, a second circuit extends from contact h^3, through train wire 31, through actuating coil of the switch 56, to ground. In the third position of the switch H, current also flows from contact h^4, to train wire 30, and thence through the actuating coil of switch 57, to ground. Therefore, when the switch H is in its "off" position, all of the resistance is included, and this may be eliminated by turning the switch through its various positions. In operation, the requisite braking steps can be obtained through the action of the controller K without necessitating the movement of switch H, and this latter switch may therefore be employed for the purpose of varying the field excitation under different conditions, namely, if it is desired to permit the car or train to attain the highest speed permissible, the switch H is left in its "off" position, namely the position wherein the field excitation is the weakest. If the conditions are such that a slower ultimate speed is desirable, the switch H may be set in that running position which will give the requisite field strength. Thus, although a large number of resistance steps may of course be provided in some instances, it may be more advantageous to have but few running positions for the field controlling switch H, these positions being marked, for example, "fast", "intermediate", and "slow" designating the ultimate speed which a car or train may obtain when the switch is set in one of those positions. It is evident that when a heavy braking action is desired the usual air-brakes may be operated in conjunction with the electric brake system. Then the train may be slowed down to the desired speed through the operation of both brake systems and be thereafter controlled electrically only.

It will now be seen that the present invention provides a simple and convenient system for effectively operating and controlling vehicles or trains under the varying conditions to be met in actual practice. In illustrating and describing my invention I have omitted many of the usual features, such as reversing switches for permitting the vehicle to be operated in either direction, duplicate master control apparatus, and various minor details of the motor controllers, since they in themselves are not necessary for an understanding of the invention. Similarly, it will be evident that various changes in the apparatus illustrated may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In an electric railway, a source of current supply, a vehicle having a motor-generator adapted to receive current from said source of current supply, series motors for driving said vehicle, and control apparatus for connecting said motors to said generator to cause the motors to operate to propel the vehicle and for connecting the motor armatures to said generator and separately exciting the series field windings of the motors to cause the motors to be driven as braking generators supplying current to the generator of the motor generator.

2. In an electric railway, a source of current supply, a vehicle having a motor-generator adapted to receive current from said source of supply, series motors for propelling said vehicle, and control apparatus adapted

to connect said motors to said generator to operate on current supplied by said generator and to connect the motor armatures to said generator in parallel with each other and the series field windings in series with each other to a source of current supply independent of the motor armatures to cause the motors to operate as braking generators supplying the generator with current

3. In an electric railway, a source of current supply, a vehicle having a motor-generator adapted to receive current from said source of supply, series motors for propelling the vehicle, and control apparatus adapted to vary the excitation of the generator field and arranged to connect the motors to said generator for operation as motors and to connect the motor armatures to said generator and the series field windings in a separately-excited current to cause the motors to operate as braking generators supplying energy to said source of current supply.

4. In an electric railway, a source of current supply, a vehicle having a motor-generator adapted to receive current from said source of supply, series motors for propelling the vehicle, control apparatus adapted to vary the excitation of the generator field and arranged to connect the motors to said generator for operation as motors and to connect the motor armatures to said generator and the series field windings in a separately-excited circuit to cause the motors to operate as braking generators supplying energy to said source of current supply, and means for varying the excitation of the motor fields when the motors are operating as braking generators.

5. In an electric railway, a source of current supply, a vehicle having a motor-generator adapted to receive current from said source of supply, an auxiliary source of current supply on said vehicle for exciting the generator field, series motors for propelling said vehicle, a resistance in the generator field circuit, and control apparatus arranged to vary said resistance and also arranged to connect the said motors to the generator armature for operation as motors and to connect the motor armatures to the generator armature and the series field windings to said auxiliary source of current supply to cause the motors to operate as braking generators.

6. In an electric railway, a source of current supply, a vehicle having a motor-generator adapted to receive current from said source of supply, an auxiliary source of current supply in said vehicle for exciting the generator field, a resistance in the generator field circuit, series motors for propelling said vehicle, control apparatus arranged to vary the amount of said resistance in the generator field circuit and also arranged to connect said motors to said generator for operation as motors and to connect the motor armatures to the generator and the field windings in series with each other to said auxiliary source of supply to cause the motors to operate as braking generators, and means for varying the resistance of the motor-field circuit when the motors are acting as braking generators.

7. In combination, an electric generator, a generator circuit, and a protective device for said generator including electro-responsive means operative at a predetermined maximum load upon the generator irrespective of the value of current.

8. In combination, an electric generator, a generator circuit, and a protective device for said generator including electro-responsive means operative at a predetermined maximum load upon the generator irrespective of the value of current, and when the current reaches a predetermined maximum.

9. In combination, an electric generator, a controller for varying the generator circuit, and a protective device including a lock for the controller and electro-responsive lock-controlling means comprising coils connected in series with and in shunt to the generator armature, said coils being wound so as to assist each other.

10. In combination, an electric generator, a controller for varying the field strength of the generator, and a protective device including a lock for the controller and electro-responsive lock-controlling means comprising coils connected in series with and in shunt to the generator armature, said coils being wound so as to assist each other.

11. In combination, an electric generator, a controller for changing the armature circuit and for varying the field strength of the generator, and a protective device including a lock for the controller and electroresponsive lock-controlling means comprising coils connected in series with and in shunt to the generator armature, said coils being wound so as to assist each other.

12. In a system of control, a source of current supply, a motor or group of motors, a controller for connecting said motor or group of motors to said source of current supply and arranged to vary the motor circuits to vary the speed of the motor, a lock for said controller, and lock-controlling means operative upon a predetermined maximum load upon the motors irrespective of the current value and upon a predetermined maximum current value to cause the controller to be locked.

13. In a system of control, a source of current supply, a motor, a controller for connecting the motor to said source of supply and varying the motor current to vary the speed of the motor, a lock for said controller, and a lock-controlling device having a coil in

series with the motor armature and a second coil in shunt to the motor, said coils being wound so as to assist each other.

14. In an electric vehicle, a motor-generator, motors adapted to receive current from said motor-generator to propel the vehicle, and an electro-responsive protective device for the system arranged to operate at a predetermined value of the current in the generator armature at a predetermined load on the motor-generator.

15. In an electric vehicle, a motor-generator, motors, means for connecting said motors for operation on current supplied by the generator or for operation as generators supplying current to the generator, and an electroresponsive protective device for the system arranged to operate upon a predetermined load irrespective of the value of the current passing through the armature of the generator of the motor-generator.

16. In an electric vehicle, a motor-generator, propelling motors for the vehicle arranged to be supplied with current from the generator, and a protective device for the motor-generator including a coil in series with the generator armature and a coil in shunt to the generator armature, said coils being wound so as to assist each other.

17. In an electric vehicle, a motor-generator, propelling motors for the vehicle, a controller for connecting the motors to the generator armature and varying the circuit conditions, a lock for said controller, and an electroresponsive lock-controlling device comprising a coil connected in series with the generator armature and a coil connected in shunt to the generator armature, said coils being wound so as to assist each other.

18. In an electric vehicle, a motor-generator, propelling motors for the vehicle, a controller for connecting the motors to the generator armature and varying the field strength of the generator, a lock for said controller, and an electroresponsive lock-controlling device comprising a coil connected in series with the generator armature and a coil connected in shunt to the generator armature, said coils being wound so as to assist each other.

19. In an electric vehicle, a motor-generator, propelling motors for the vehicle, a controller for connecting the motors to the generator armature and having contacts arranged to vary the circuit conditions and the strength of the generator field, a lock for said controller, and an electroresponsive lock-controlling device comprising a coil connected in series with the generator armature and a coil connected in shunt to the generator armature, said coils being wound so as to assist each other.

20. In combination, a motor-generator, motors, control apparatus adapted to connect said motors to the generator of the motor-generator for operation as motors or for operation as generators driven by the load and to vary the speed of the motors, a protective device for the motor-generator including an electroresponsive device having coils in series with and in shunt to the armature of the generator, said coils being wound so as to assist each other, and means for reversing the connections of one of said coils upon changing the motors to braking generators and vice versa.

21. In combination, a motor-generator, series motors, control apparatus arranged to connect said motors to the generator of the motor-generator to cause the motors to operate as motors or to connect the motor armatures to the generator armature and the motor field windings to a separate source to cause the motors to operate as generators driven by the load, said control apparatus including means for varying the generator field both when the motors are operating as motors and as generators together with means for varying the excitation of the motor fields when separately excited.

22. In combination, a motor-generator, series motors, control apparatus for varying the field excitation of the generator and for connecting the motors to the generator for operation as motors or for connecting the motor armatures to the generator and the motor field windings to a separate source to cause the motors to operate as generators driven by the load, and separate means for varying the excitation of the motor field windings during the operation of the motors as generators.

In witness whereof I have hereunto set my hand this 4th day of April, 1906.

EDWARD H. ANDERSON.

Witnesses:

BENJAMIN B. HULL,

HELEN ORFORD.